GAAR Engineering Firm
(Gael Hansen, Alan Ramirez, Ariel Novodvorschi,
Rayyan Marediya)

Fariborz Maseeh Building Proposal

Accommodating the Growth of Civil, Architectural, Environmental Engineering in the 21st century

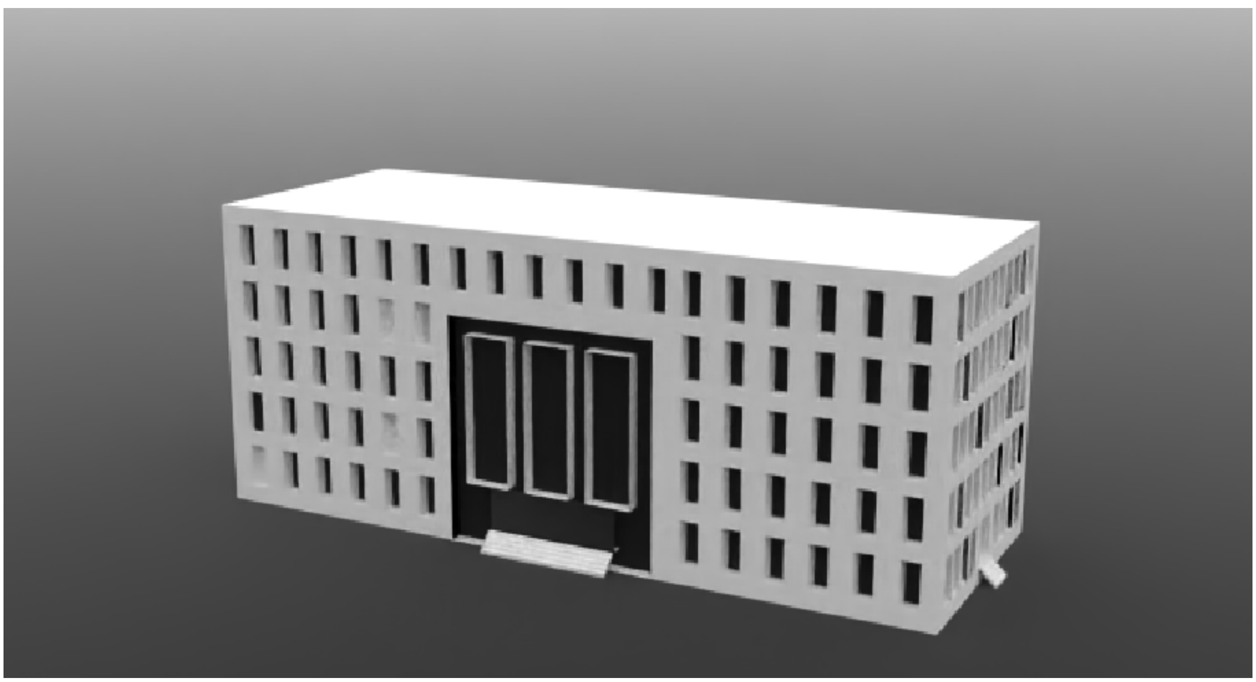


Table of Contents

Executive Summary

The current Department of Civil, Architectural, and Environmental Engineering is one of the largest departments within the Cockrell School, and its enrollment has grown by 25% within the last decade. In addition, a new major, Environmental Engineering, has been created in 2017 and it becomes apparent that the CAEE Department needs a new home. With this growth in mind, GAAR Engineering has outlined a plan for the construction of the Fariborz Maseeh Building (FMB) that includes the design, changes to transportation system, a drainage system, the structural frame design, and the foundation. Furthermore, all aspects of the FMB's design will house a 29% growth to account for present and future growth of the CAEE department.

The transportation systems of the FMB take into account the accessibility of the building as there is a high volume of foot traffic on the building's intersecting roads, Dean Keeton and Speedway. In addition, a new building will attract many students, faculty, and other visitors, we estimate will cause a great change in pedestrian and vehicular traffic which needs to be accounted for. During peak hours, approximately 2200 individuals presently utilize the crosswalk each hour. With a 25% increase, it is anticipated that the number of crosswalk users will rise to 2750 people per hour. There will be an adjustment for the signal timing for the Dean Keeton St. and Speedway intersection that will better balance the influx in pedestrians with existing car traffic without changing the underlying cycle duration.The construction of the new FMB will pose a challenge in space allocation and may make the existing traffic even more difficult, but we think designing a new signal can alleviate some of these concerns. After experimenting with different combinations, we propose a 57.33 second delay for vehicles on Speedway and a 17.21 second delay for vehicles on Dean Keaton. The resulting average delay per vehicle is calculated to be 22.71 seconds. We also propose a new transportation system with a newly converted trash and delivery route connecting Speedway to San Jacinto Boulevard, replacing the existing sidewalk path with a new one to the left of our new building, and creating new bike racks for the growth in scooters and bike usage. Since we are leveling out the site, we do not need to include ramps for accessibility.

Creating a new building means there will be changes to runoff in storm events which need to be evaluated. To design for the future and the battling climate change, the storm drainage has been designed for a 100-year rain event that will use large pipes to direct water to Waller Creek to the east of the location. Our main drainage pipe had a diameter of 15 in which was calculated using our total Q-value of 3.06 ft^3, a slope of 0.0844 from our building to Waller Creek, and an n-value of 0.012 for the concrete material. We chose concrete because it is durable, contains high compressive strength, is resistant to corrosion, minimizes resistance to water flow, has a low environmental impact, and is cost-effective. The extra runoff from our construction is 1.8566 ft^3/second which represents how much extra runoff will be drained into Waller Creek. In anticipation of global warming's impact on runoff, we recalculated our runoff using updated i and q values and obtained the same value as before of our pipe diameter. This means our building includes a growth in runoff from now until the end of the century.

To accommodate this initiative, we must construct a structurally sound building by designing columns capable of withstanding the necessary live and dead loads. Generally, gravity loads transfer to the structural components through the connections, lateral loads like wind or earthquakes could transfer to the bracing and shear walls, and the structural loads transfer down through the columns to the foundation and then spread evenly in the soil. Our column will be 10 ft in height with a square base of length 1.3 ft. The total load of and on the building will be 8,082.18 tons which includes both live and dead loads. The calculated load each column needs to bear is 593,781.33 lbs per column (296.9 tons/column) which includes a safety factor of 2. Since the maximum load a column can bear is 13,530.5 tons, we exceed the load-bearing requirement of our building.

The next thing to consider in the design and construction of our building is the foundation which is integral. The foundation must support the loads from each column to prevent general shear failures which occur when the shear stress of the foundation's surface exceeds the maximum shear strength of the soil causing the footing to collapse. To ensure this failure does not occur, we calculated a foundation design using the given load of 5 million pounds (10 million pounds with safety factor of 2) to construct a safe but also cost-effective building. Using Python, we estimated a depth value of 8 ft and a square base with a value of 12 ft, and the total cost would be $172,540.

This building seeks to be cost effective while maintaining the needs of the CAEE Department with its design. It will be a strong building that will be prepared for the future and all weather events while also preparing the next generation of civil, architectural, and environmental engineers that will shape the 21st century.

Introduction

In response to the growth of the student population within the civil engineering, environmental, and architectural department (CAEE), we present a forward-thinking design proposal for a new building tailored specifically to meet the demands of today's CAEE students. This proposal outlines not just a physical structure, but a dynamic learning environment meticulously crafted to foster collaboration, innovation, and hands-on learning experiences. With a keen focus on sustainability, technology integration, and flexible spaces, our design aims to inspire the next generation of engineering leaders.

Campus Master Plan

As of 2009, the Cockrell School master plan has planned for 6 new engineering buildings which include 1,000,000 square feet in classrooms, labs, and offices, to accommodate the growth in engineering. Since the creation of the master plan, the Cockrell School has opened the Biomedical Engineering Building (BME), the Engineering Education and Research Center (EER) and the Gary L. Thomas Energy Engineering Building (GLT). Keeping future growth in mind, The University of Texas at Austin master plan has outlined several locations for potential new buildings for the engineering department. One location proposed is in front of the Chemical and Petroleum Engineering (CPE) building north of Dean Keeton Street. GAAR Engineering has designed a site plan located in front of the CPE for the new Fariborz Maseeh Building (FMB), named after the Maseeh Department of Civil, Architectural, and Environmental Engineering (CAEE), that will accommodate the needs of that department.

Philosophy of the Fariborz Maseeh Building

The current Ernest Cockrell Jr. (ECJ) Hall was built in 1974 and does not meet the needs of the current CAEE Department that it houses. Currently, there are 10 floors and a basement with designated floors for labs, classrooms, lecture halls, faculty offices, and the Cockrell School Dean’s office. However, the ECJ needs more undergraduate student-centered spaces as it currently prioritizes faculty offices and graduate-level study on each floor. The FMB proposal would be a modern building that would fit the needs of 21st-century engineers and reflect the values of the contemporary design as seen in the EER and GLT. The design will prioritize sustainability, incorporate green spaces, and include a pedestrian centered design that maximizes foot traffic accessibility while still housing space for low car volumes. GAAR Engineering’s design is focused on undergraduate study and providing space for primarily students. Similar to the EER and GLT, there will be an emphasis on large open spaces, outdoor light to illuminate the building, and more engaging and inviting rooms to collaborate with other engineers. The goal is to connect the current engineering student population, both in and outside the CAEE Department. Currently planned is an intimate experience between students where the building will be five stories tall consisting of open floor plans, increased study spaces, and a food court. To keep continuity with the current ECJ and other engineering buildings built before the 2009 Cockrell School plan, the basement floor will house state of the art laboratory equipment and the top floor will be used for the academic advising office. The student centered amenities, a key aspect of the building’s design, will be located on floors two through five.

Needs of CAEE Students and Staff

The current CAEE building, the ECJ, mainly consists of faculty offices and laboratories, which is not sufficient for the growing student population. As the CAEE department has grown, so has its needs for additional amenities. These amenities include study spaces, food options, and classrooms. The new facilities in the FMB will provide students with the spaces to maintain an optimal learning environment.

Calculations and Growth Projections of CAEE Department

The employment of civil engineers is projected to grow 5 percent from 2022 to 2032. Furthermore, about 21,200 openings for civil engineers are projected each year, on average, over the next decade. The growth of the field of civil engineering has also become evident at the University of Texas at Austin. Over the last decade, the number of students in UT Austin’s CAEE program has increased by 25%. Furthermore, this number is expected to grow as the field of civil engineering continues to grow. To account for present and future growth, we recommend establishing an extension to the ECJ that is 29% of the size of the ECJ building. The current ECJ building is 240,246 ft^2, therefore the new building will be 69,790 ft^2 which is 29% of the square footage of the current ECJ building. The new building will have 5 floors so to have an equal amount of square footage per floor, each floor will be 12,250 ft^2 besides the basement which is 8,540 ft^2.

Current Infrastructure in the Chemical Petroleum Engineering Lawn

There is a relatively low level of infrastructure already on the new site which includes a police help booth and a clock not art structure. The Clock Knot is of a considerable size and poses a challenge in construction. It either needs to be moved or built around, however, building around it may limit space on the bottom levels. Regarding lighting, there are 6 light posts along the perimeter of the Clock Knot which display lights at the base of the structure. The transportation facilities in the development site and around the CPE include one main sidewalk connecting a diagonal path from the street and a straight path through other engineering buildings. Regarding access, there are two sets of bike racks on either side of the rectangular site along with outdoor seating. There are no water facilities currently or telecommunication lines. A notable structure to consider are the prebuilt structures along the side closest to the highway/street that have three levels of brick layering with green/gardening elements. There is a large wall along the edge of this layering. The topography of the area does pose a challenge as the area is heavily sloped along the sides of the rectangular area and levels off in the middle. The topography is not completely irregular but may pose trouble in construction.

Design

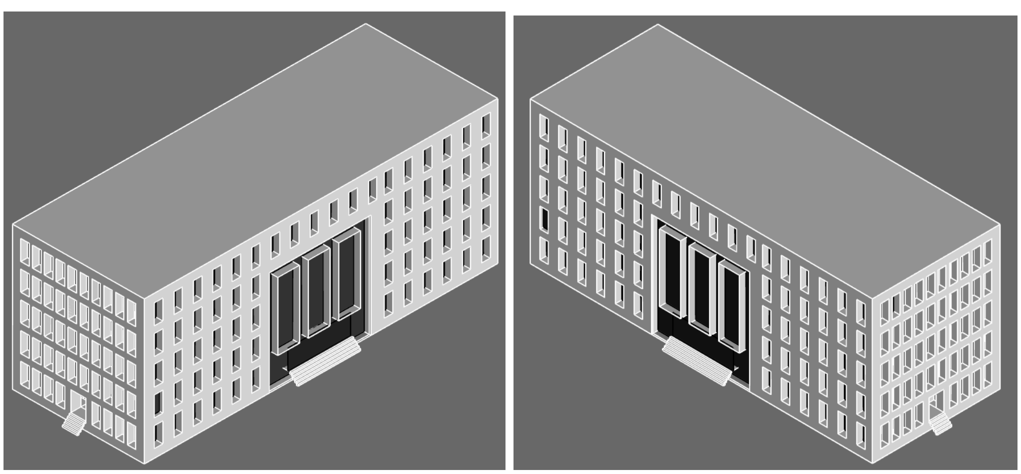


Figure 1: Rendered Isometric Views of the FMB

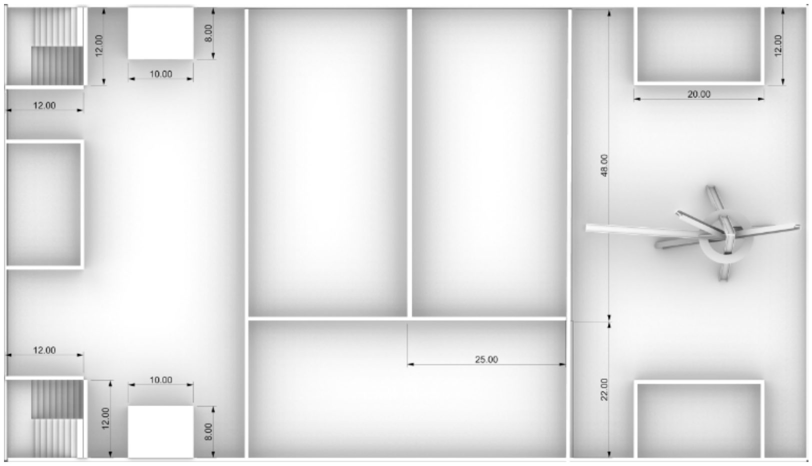


Figure 1.1: Basement Level Floor Plan with Clocknot

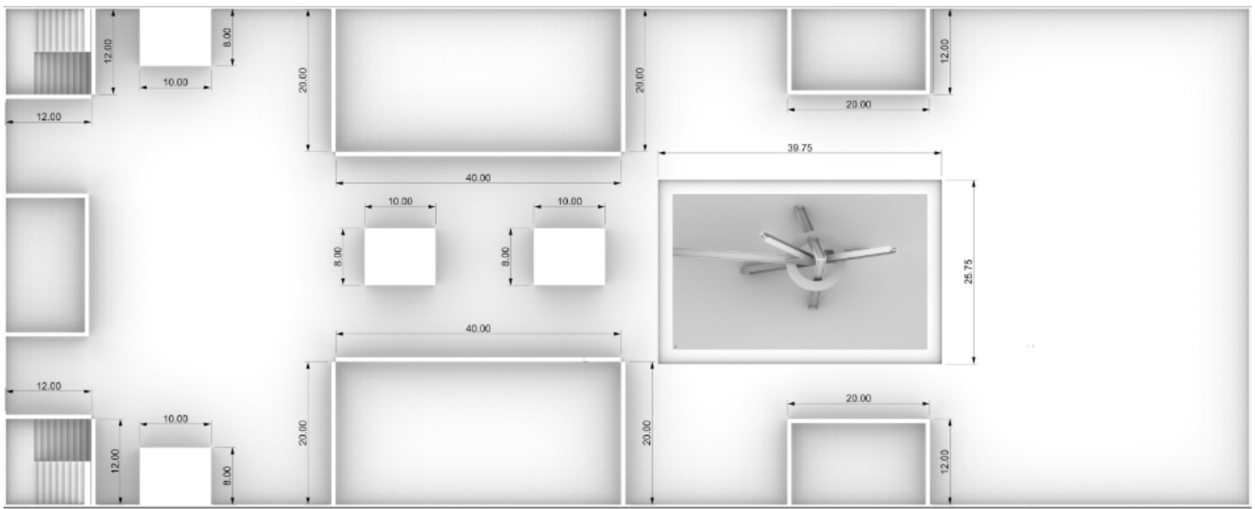


Figure 1.2: Rendered Floor Plan of the Ground Level with clocknot and space for a food court.

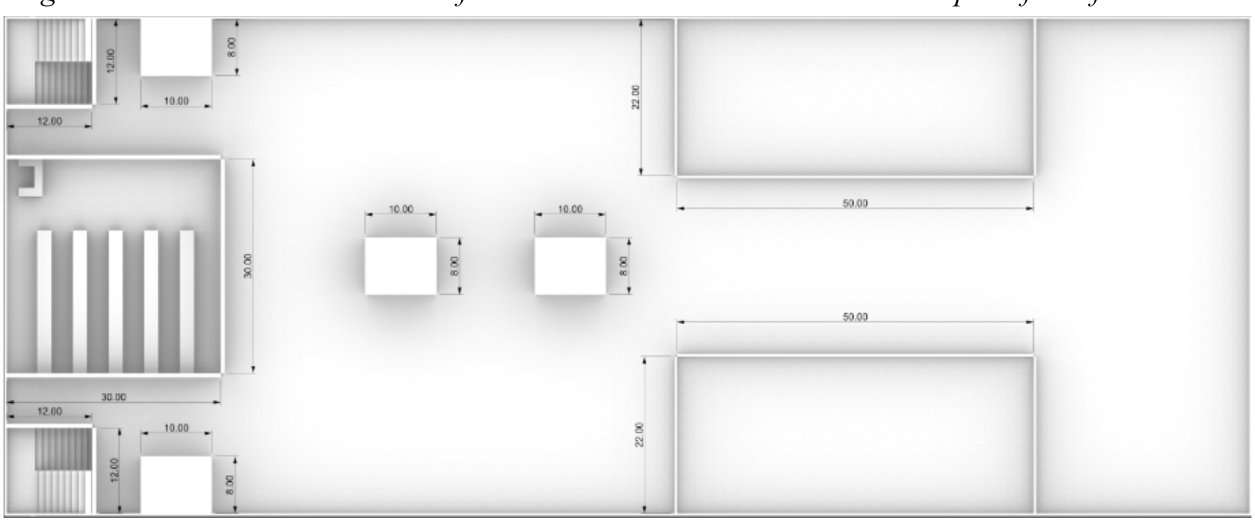


Figure 1.3: Rendered Floor plan of Floors 3, 4, and 5 showing dimensions of classrooms and computer lab.

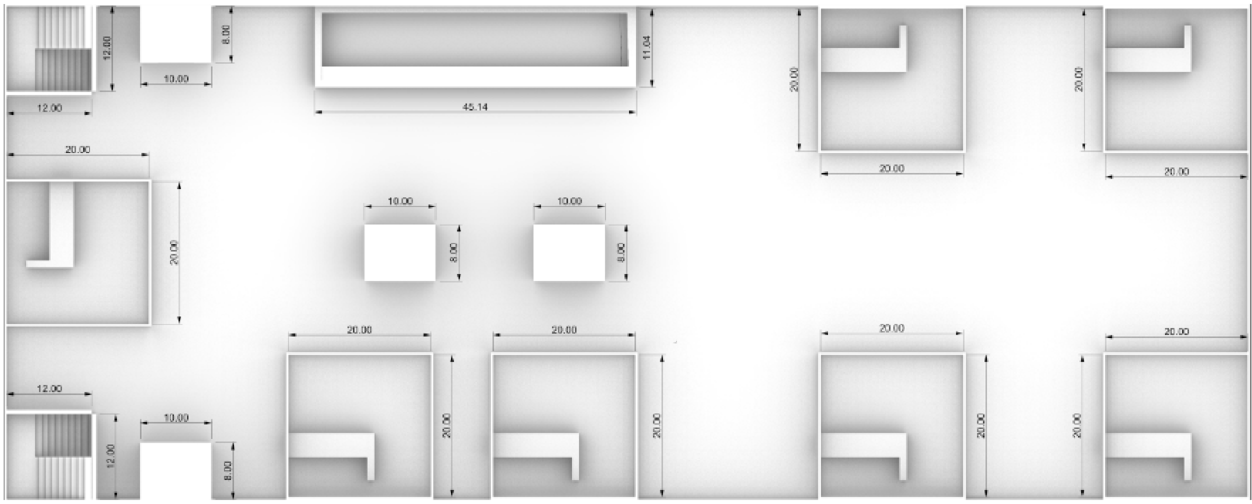


Figure 1.4: Rendered floor plan of Floor 6, showing dimensions of advising offices and reception desk.

Drainage System

Runoff and Pipe Diameter Calculations

From the City of Austin's drainage criteria manual, we found an i-value of 9.16 in/hour (by 15-minute duration). We considered the types of ground cover we would be implementing in our design and chose roof, asphalt (for sidewalks), and grass/lawns for the remaining area.

- Our c-values for the roof, asphalt, and lawns were 0.95, 0.95, and 0.35 respectively.
- Using the formula Q=ciA, we calculated the runoff for the roof, asphalt, and lawns to be 2.62 ft^3, 0.32 ft^3, and 0.12 ft^3 respectively. This in total was 3.06 ft^3.
- Our area in square feet for the roof was 13,125 ft^2 (75 ft x 175 ft) which is 0.301 acres.
- Our total area in square feet of grass (before construction) is 16,302 ft^2 (78 ft x 209 ft) which is 0.374 acres.
- The difference between our roof square footage and the existing lawn area (0.073 acres) was split in half (0.0365 acres) for the area for sidewalks and for a new lawn area.

To calculate the diameter of our main drainage pipe, we first considered the material of our pipe which was concrete. Using the n-value for concrete of 0.012, a total Q-value of 3.06 ft^3, and a slope of 0.0844, we were able to calculate the diameter of our pipe.

- Our slope was calculated using the fact that the site is 554 ft in elevation, Waller Creek is 523 ft in elevation, and they are 367 ft apart.
- We used the formula $Q=1.49\pi^2/128n \cdot d^{8/3}\sqrt{S}$ to calculate our diameter
- Our calculated diameter was 1.04 ft or 12.48 in. Our standard pipe diameter was 15 in.

Justification of Material

Choosing concrete as a pipe design material for the Fariborz Maseeh Building (FMB) offers various advantages, such as durability and cost-effectiveness, making it an exceptional option.

Below is an in-depth analysis that provides several key justifications for selecting concrete as a pipe design material.

1. Durability:
   - Concrete pipes are well known for their durability as the average lifespan of concrete pipes is around 75 to 100 years. They are able to withstand an expansive range of environmental conditions, including but not limited to extreme temperatures, toxic chemicals, and illuviation.
   - Due to their long-lasting shelf life, concrete pipes present themselves as a cost-effective solution over the long term.

2. Strength:
   - Concrete exhibits a high amount of compressive strength, thus making it capable of withstanding significant magnitudes of loads and pressure. The importance of concrete's strength plays a role in maintaining the structural well-being of the pipes under various utilization conditions.

3. Resistance to Corrosion:
   - In contrast to some metal pipes, concrete has a high resistance to being damaged by harmful chemicals or other corrosive substances. This serves as an advantage in environments where corrosive materials may be present. Furthermore, concrete's low susceptibility to chemical corrosion makes it an ideal choice for sewer and stormwater drainage.

4. Hydraulic Performance:
   - The rigid structure of concrete pipes minimizes resistance to water flow while still maintaining its original shape and configuration allowing it to outperform flexible pipe systems. In essence, the smooth nature of concrete pipes allows for hydraulic efficiency.

5. Low Environmental Impact:
   - Concrete's durability and strength make it an environmentally friendly option as it produces a lower environmental footprint over time in comparison to other materials. Additionally, concrete can be made from recycled materials, thus aligning with sustainable construction practices.

6. Cost-Effective:
   - Flexible pipe materials may initially have a lower cost than concrete, however, their low durability makes concrete a more cost-effective solution over time. Concrete's long service life and minimal maintenance requirements signify that it offers an economical selection for sewer and stormwater drainage systems.

In conclusion, concrete as a pipe design material is an exceptional option due to the material's durability, strength, performance over time, and cost-effectiveness. The characteristics of concrete enumerated in the list above make concrete pipes a reliable and suitable option for the drainage systems of the Fariborz Maseeh Building.

Extra Runoff Added to Waller Creek

Constructing a large campus building like the new Fariborz Maseeh Building (FMB) will greatly alter the amount of runoff generated and consequently drained into Waller Creek. To evaluate how much water will be added, we must look at the current state of the site and its runoff and compare it to the potential site's runoff.

- As calculated above, the new site's runoff quantity will be a total of 3.06 ft^3/second considering the addition of roof area, asphalt for sidewalks, and existing grassy/lawn area.
- The current state, which only consists of grass/lawn, has a total runoff quantity of 1.199ft^3/second.
- The difference between the two is 1.8566 ft^3/second which represents how much extra runoff will be drained into Waller Creek

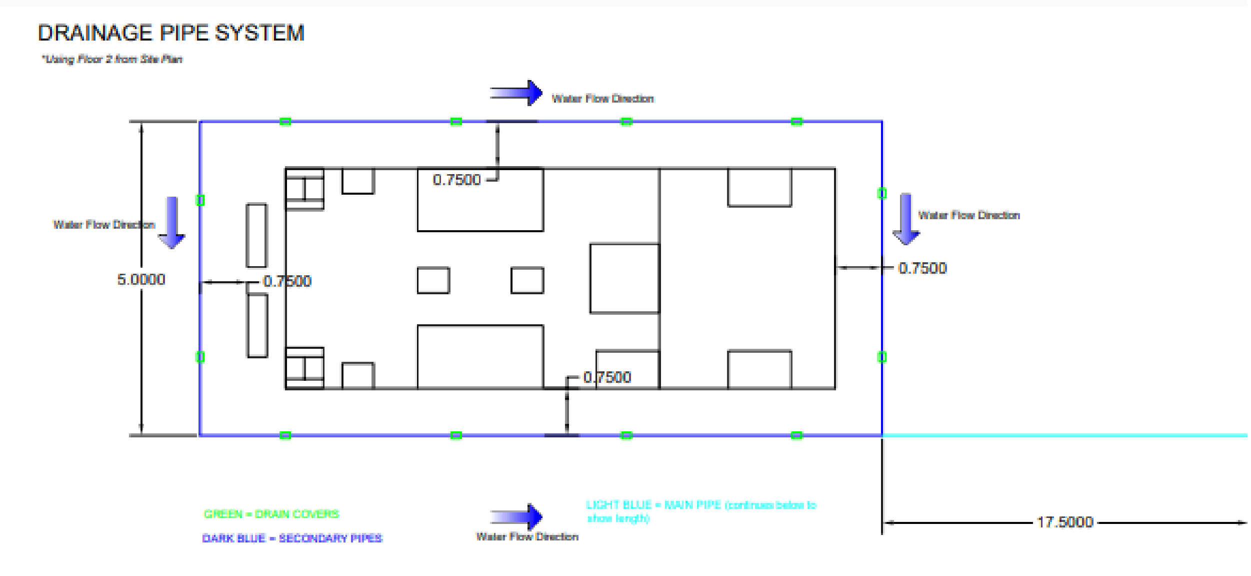


Figure 2: Line sketch of the Drainage system showing water flow direction and perimeter of the system.

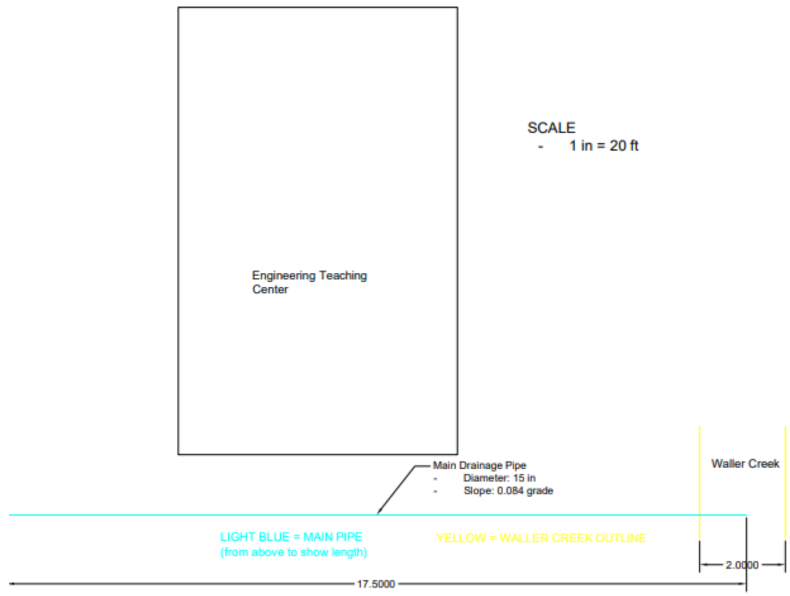


Figure 2.1: Line sketch of the Main pipe of the system showing its dimensions and endpoint.

Climate Change Impact on Drainage System

An increase in global warming leads to an increase in how warm oceans can get. Warmer oceans lead to an increase in the amount of water that evaporates which creates more moisture in the atmosphere. When this air converges, intense precipitation can occur. In these intense precipitation events, crop damage, flood risks, and even a rise in water pollutants can occur which are disastrous on their own.

According to studies on global warming and its impact on intense precipitation events, from the 1910s to 2020s, there has been an overall increase of 0.5% per decade in land area affected by intense precipitation events. In a separate study, it is reported that from 1901-2016, in the Texas region, there has been a 24% increase in total annual precipitation resulting from the heaviest 1% of events. From 1958 to 2016, it was a 12% overall increase. From current times to the end of the century, Austin will experience around a 20% increase.

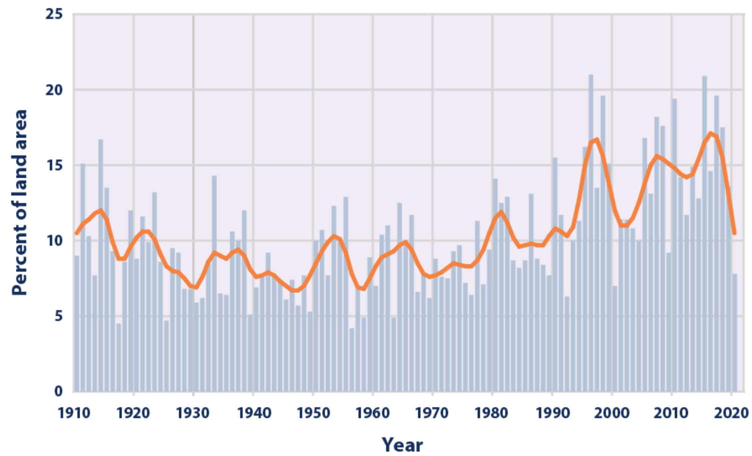


Figure 3: Extreme One-Day Precipitation Events from the 1910s to 2020s

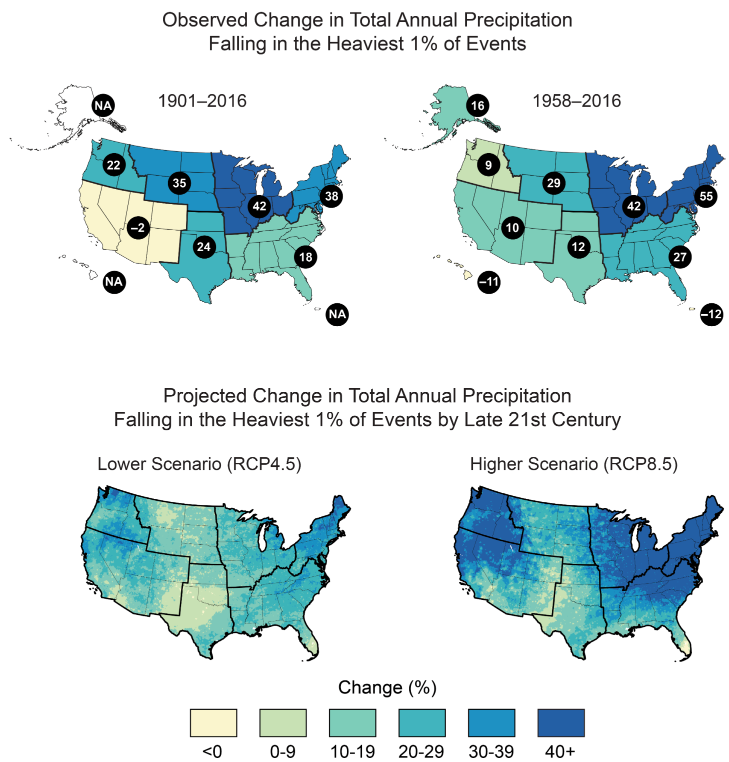


Figure 3.1: Change in Total Annual Precipitation from 100-Year Events

This section is designated for calculating the runoff generated by 100-year rainfall events or events that have a 1% chance of occurring in a given year. From this calculation, we were able to design a drainage system with a diameter and slope that could accommodate this heavy flow. However, if global warming persists in the current trend, then the new design for the drainage system may be ineffective in the long run.

- Assuming a 20% increase would occur for the intensity value of precipitation, from the current i-value of 9.16 in/hour would increase to 10.992 in/hour by the end of the century.

To see if the current design would last until the end of the century, the following calculations were conducted:

	i value (15 min)	Q value (total)	Extra Runoff	Diameter	Standard Diameter
Current	9.16 in/hour	3.06 ft^3	1.861 ft^3	12.48 in	15 in
End of Century	10.992 in/hour	3.66 ft^3	2.461 ft^3	13.44 in	15 in

Our calculations showed us that our design for the drainage system would not need to change by the end of the century or need to be renovated as the standard diameter would stay the same. This is likely due to the fact that the difference between the current Q value and the End-of-Century Q Value is minimal. However, the extra runoff into Waller Creek would actually increase from the current design to the end of the century.

Signal Design

Current Challenges Facing Providing Transportation

As part of the proposal of the new Fariborz Maseeh Building (FMB), GAAR Engineering must analyze the current Dean Keeton and Speedway intersection located in front of the FMB site. One of the most important aspects of erecting the proposed building is the amount of foot traffic on the site and providing pedestrian accessibility to the building. The new Civil Engineering campus cannot function without any users, thus, it is important to make an analysis of the current and future states of the users and challenges of the area.

One consideration in the FMB site is the Dean Keeton and Speedway intersection in front of the site. Dean Keeton Street is a 4-lane vehicle road that shares the space with buses, personal automobiles, bicycles, scooters, pedestrians, and on-street parking. One half of Speedway, located on the south side of the intersection is a pedestrian road that limits the number of heavy duty vehicles and maintenance vehicles and prioritizes pedestrian traffic. The other half of Speedway, located north of the intersection, is a 2-lane road with bicycle lanes and on-street parking. To accommodate the needs of university students, the intersection allows for large volumes of automobiles, then large volumes of pedestrians by allowing pedestrians to cross in all directions and not allowing cars to pass through. However, due to the large size of the road and its car traffic, it is impossible to cross the street without waiting for the pedestrian intersection light or taking the ECJ bridge that is out of the way for many.

The footprint of the FMB site is quite small, which may make the space difficult to share between delivery vehicles, bicycles, scooters, and pedestrians. With the construction of the FMB, space will be very limited, however, strategically planning the location of the FMB might be able to accommodate the maximum number of pedestrians. Additionally, the hilly terrain of the site may prove challenging for those with physical disabilities, and it must be addressed to assure the accessibility of the FMB, CPE, and ETC. Ramps might need to be installed in the location, and the site will have to be excavated to ensure that any inclinations are not too steep. As of now, theren't aren't any inclinations that are too steep for wheelchairs, scooters, or bicycles, nonetheless, it is a challenge that must be taken into account. Lastly, the pedestrian traffic originating from the EER and ECJ must be taken into account when planning the traffic flow into and out of the FMB site.

Estimates of Pedestrians Using Dean Keeton and Speedway

GAAR Engineering conducted a study to calculate the amount of people that currently use the pedestrian crossing on Dean Keeton and Speedway. The study was done by counting the amount of people crossing on one side to get to Dean Keeton and counting the amount of people crossing on the other side to get to Speedway. This study was conducted within a 15 minute time frame during a passing period to be able to get an accurate reading on how many people cross every hour. The current pedestrian flow rate on Dean Keeton and Speedway is 550 people crossing per 15 minutes. The data collected during the 15 minutes was then multiplied by 4 to estimate how many people currently use this crosswalk every hour. It was estimated that a total of 2,200 people use the crosswalk on Dean Keeton and Speedway every hour during peak hours. The number of crosswalk users includes pedestrians, scooters, skateboards, and bicycles. Once the FMB is established it is expected for the number of crosswalk users to rise by 25%, therefore the estimated future number of hourly crosswalk users is 2,750 people per hour. In the next section of this report, we will examine the best option for a new signal timing for the lights on Dean Keeton and Speedway that will accommodate the rise in crosswalk users.

A Proposal For a New Signal Timing

Based on the collected data, GARR Engineering has implemented adjustments to the traffic signals along Speedway and Dean Keeton. By reducing the signal times by two seconds at each intersection, four additional seconds are allocated for pedestrian crossings while maintaining the cycle length. Consequently, it is projected that vehicles on Speedway will experience a 57.33-second delay, whereas vehicles on Dean Keeton will encounter a 17.21-second delay. This discrepancy in delay times between the two roads is rationalized by the notably lower traffic volume observed on Speedway compared to Dean Keeton. The resulting average delay per vehicle is calculated to be 22.71 seconds.

Phase	Volume (q_i)	Saturation flow (s_i)	Green time (G_i)	Capacity c_i	X_i	Delay d_i
1(Speedway)	166	3610	11 s	330.916	0.5016	57.33
2(Dean Keeton)	1046	8590	60 s	4295	0.2435	17.21

Rationale of Transportation Sketch

The sketch uses the Fariborz Maseeh Building (FMB), the Engineering Teaching Center (ETC), and the Chemical and Petroleum Engineering Building (CPE) to display the new transportation system. The new system will turn the areas between the buildings into a delivery/trash route connecting Speedway to San Jacinto Boulevard. We believe that creating the FMB would require removing the existing sidewalk path and the garden area in the middle. Therefore, the remaining space could be used to create a path connecting the back of the FMB with the front of CPE and the side of ETC. The sidewalk path that was removed would be relocated to the left side of FMB to accommodate the new flow of foot traffic. Regarding bike racks, there are already existing bike racks along the front of the CPE building and the side of ETC, but assuming there will be a 25 percent growth in scooters and bikes, two additional bike racks will be placed alongside the left side of FMB. The new delivery route, which ranges from 43 feet to 60 feet in width, will have plenty of space for large trucks and other vehicles to maneuver and will reduce congestion in the backside of the CPE area. The new pedestrian transit including the existing bridge will accommodate the growth in foot traffic, and the bike racks, including the two new ones, will accommodate the growth in bike/scooter use. Regarding the inclines and accessibility, since the left side of FMB is relatively flat, ramps will not be necessary as the new sidewalk path will be leveled out.

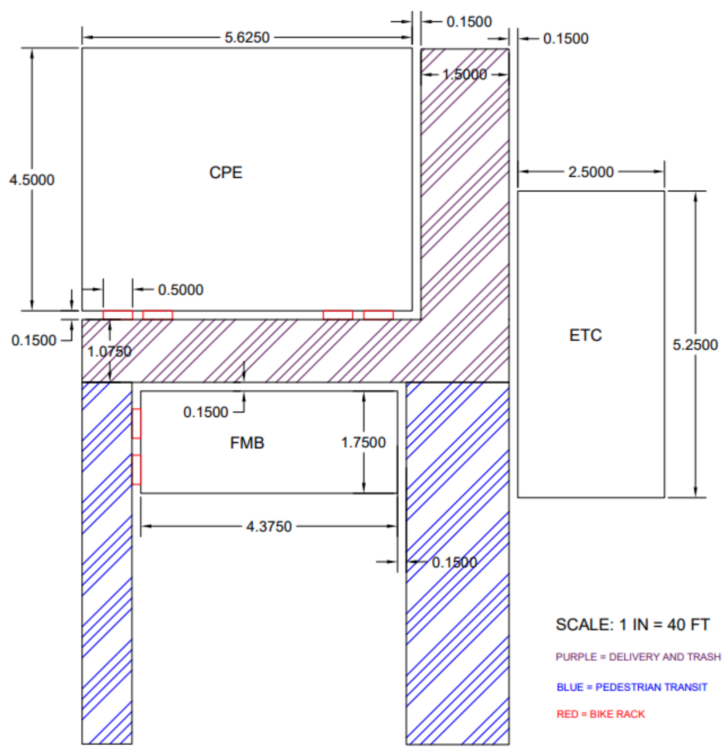


Figure 4: Line Sketch of transportation access to the FMB

Structural Plan

Column Design

The design for the column is a concrete column that is 10 feet high and 1.3 feet wide with a square base. The supports for the column will be fix-fix supports. The calculated load of the building is 16,164,352.54 lbs, which is equal to 8,082.18 tons, this includes the dead load and live load that the building will need to withstand. For safety purposes, the load requirements of the building's columns include a safety factor of 2, therefore the building needs to be able to withstand 32,328,705.08 lbs (twice as much as the estimated load). To determine the load that would be placed on each column, the total load of the building was multiplied by the ratio of the tributary area to the area of an individual floor of the building. The calculated load that each column will need to bear is 593,781.33 lbs per column (296.9 tons/column) - this number includes a safety factor of 2. Using the dimensions of the beam, the maximum load that any one of the columns can bear before buckling due to compression is 13,530.5 tons, therefore satisfying the load-bearing requirement of the building's columns.

How The Load Will Transfer

The load from non-structural components of the building including the windows, and doors will transfer to the structural components of the building. Gravity loads will transfer to the structural components via the connections they make with the surrounding elements. For example, the weight of the wall is transferred to the floor through studs. The buildings will resist lateral loads such as wind and earthquakes and might transfer them to the bracing and shear walls. The building tends to support loads from the plumbing and electrical components. How the structural components transfer load to the foundation is via the foundation. Vertical loads from structural components are transferred downwards via columns and the walls to the foundation and spread throughout the soil to prevent building collapse and ensure stability and structural integrity.

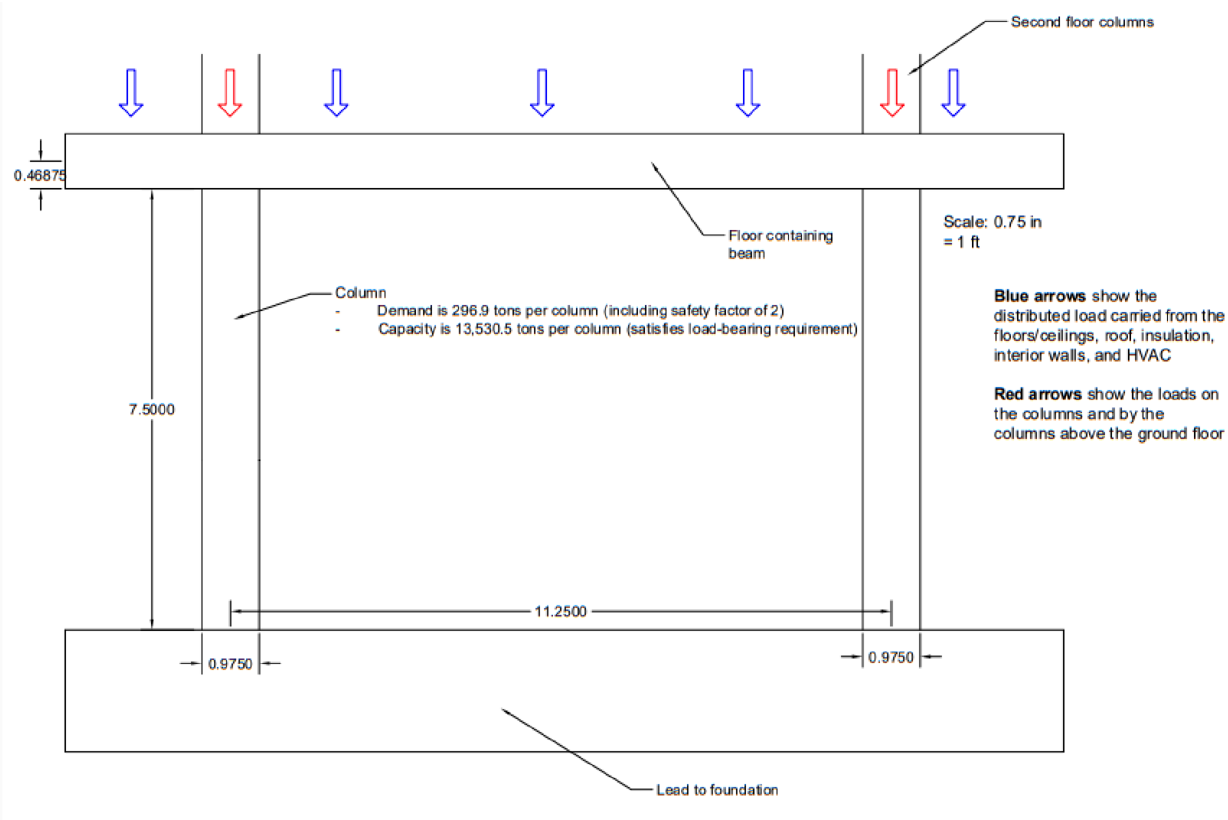


Figure 5: Line sketch showing distribution of load onto the columns.

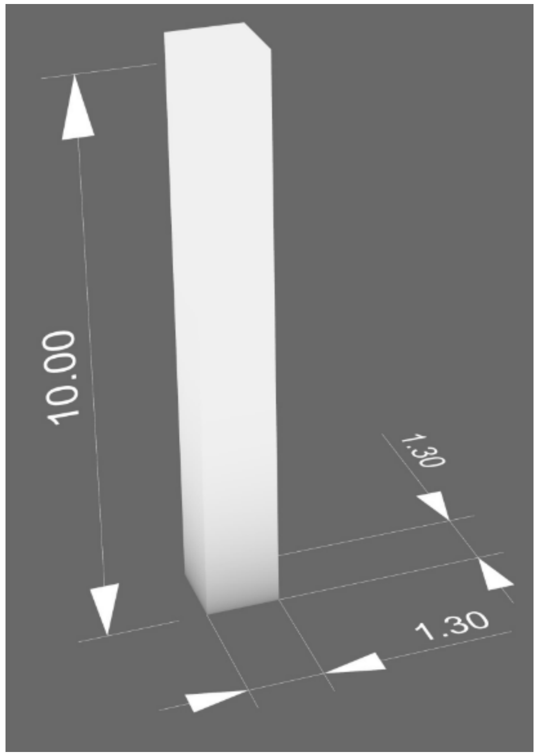


Figure 5.1: Rendered Model of the column showing its dimensions in ft.

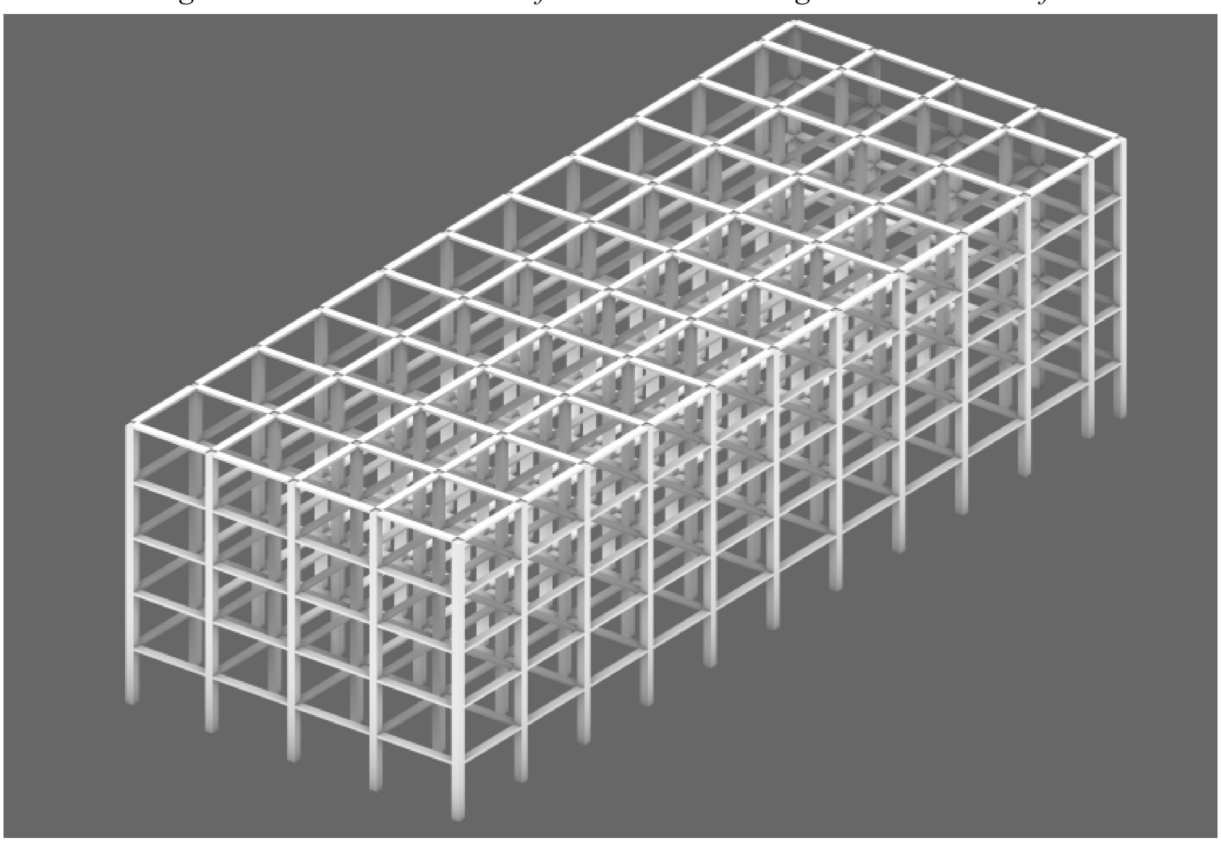


Figure 5.2: 3D model of the structural frame of the FMB.

Foundation Design

Description

The purpose of this report is to propose a design for the building's foundation that will adequately support the load from each column without failing. One of the most common footing failures is a general shear failure, which occurs when the shear stress of the foundation's surface exceeds the maximum shear strength of the soil causing the footing to collapse. To ensure that a general shear failure will not occur, a structure's foundation must be able to withstand a load that is higher than the maximum load of the building by a safety factor of 2. The load that the foundation can withstand is known as the footing's bearing capacity. The footing's bearing capacity can be calculated using the material properties of the soil, the depth of excavation done to place the foundation, and the dimensions of the structure's foundation. The quantities already calculated include the material properties of the soil and the depth of excavation, thus we will be using these values to calculate the proper dimensions of the foundation to certify that they will satisfy the load-bearing requirements needed to protect the footing from collapsing.

Approach to Design Problem

We used the 5 million pound load that was provided as a basis for our foundation design approach. Furthermore, we must ensure a safety factor of two in our load calculations due to unforeseen circumstances that may occur, such as unpredictable weather and conditions that could harm the building or even topple it if the given conditions were strong enough. Additionally, we will be using Python to perform the cost and load calculations of our foundation design. As engineers, we must minimize costs as many projects tend to go over budget, thus we must ensure that all parties are satisfied by having the lowest possible price tag associated with our design. We will take into account the constrictions of our project and price per square foot when calculating the minimum cost. After building the cost and parameters equations, we can then use python to find the minimum cost for designing and constructing the foundation of the building.

Calculations

The load we calculated from our last activity gave us a value of 34,055,267 lbs which includes a safety factor of 2. However, this value is greater than 5,000,000 lbs, so we used 5,000,000 lbs instead for our load calculation which would be 10,000,000 when including a safety factor or 2. We used the equation $Q_{ult} = s_u \cdot N_c \cdot s_s \cdot d_c$ for our fundamental calculations. We were given the values for s_u, N_c, and s_s which were 10,000 psf, 5.14, and 1.2 respectively. The last value, d_c, was equivalent to $1 + 0.2(\frac{D_f}{B})$ where D_f is the depth of the footing and B is the shorter dimension of the footing. It's important to consider, though, that our Q_{ult} value needs to be divided by B^2. We need to find values of D_f and B that gives us a value (Q_{ult}) that is greater than or equal to our load of 10,000,000 (Q_{max}). In other words, our final equation is 10,000,000 = 61,680B^2 + 12,336 $D_f \cdot B$ which was derived after inputting our given values and making a function with two variables D_f and B. The left-hand side represents our Qmax and the right-hand side represents Qult.

Now that we have an equation for our load, we need an equation to represent our cost. $1500 is the fixed price of the footing, it costs $1000 per square foot of the footing size, and the cost of excavation is $20 per cubic foot. From our given constraints, we know that the footing must be at least 1 foot larger on each side compared to the size of the footing. After including these values and constraints, we have the equation $1500 + 20(D_f(B+1)^2) + 1000B^2$ which represents our total cost.

Because manually inputting values for D_f and B that make both of the above equations true would be very time-consuming, we used Python to code a program such that both equations would be true. There are some additional constraints we had to consider for our code: the footing must be at least 2 ft below the ground, it must be square, and no more than 12 feet by 12 feet. The depth of the footing must also be no more than 20 feet. Since we were not given a value the depth of the footing must at least be, we assumed that the lower limit would be the same as the footing (2 ft). We then inserted all these values, constraints, and equations into Python for our final computing. Our final values for our foundation design were 8 ft for our depth and 12 ft for each side of our square base with a final cost of $172,540.

** Refer to Appendix D for Python code and corresponding explanation.*

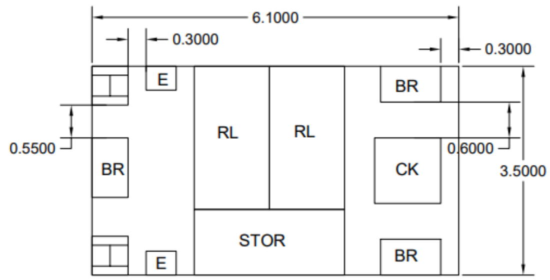
Conclusion

GAAR Engineering proposes the design of the Fariborz Maseeh Building as an extension of the CAEE department in preparation for the present and future growth of its student population. This building will serve as a central study location where people can gather to study and collaborate while having room for classrooms, laboratories, and the CAEE advising faculty. Its emphasis will be on student amenities in the spatial layout, while its architectural concept will reflect the core principles of modern engineering: sustainability, prioritizing human needs, and future adaptability. The current blueprint takes into account transportation and drainage systems, and structural and foundation design. In addition, the building will serve as a benefit to both the students and faculty as it will improve the land usage of the campus. Overall, the goal of erecting the FMB is to adapt to the growing CAEE student population and offer a student centered space which will inspire future generations of engineers to come.

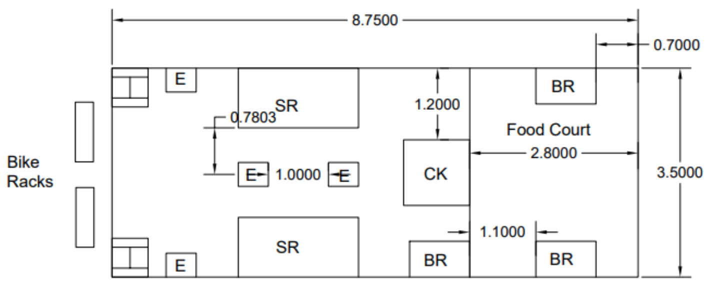
Appendix

Appendix A: Line Sketches of FMB Floor Plans

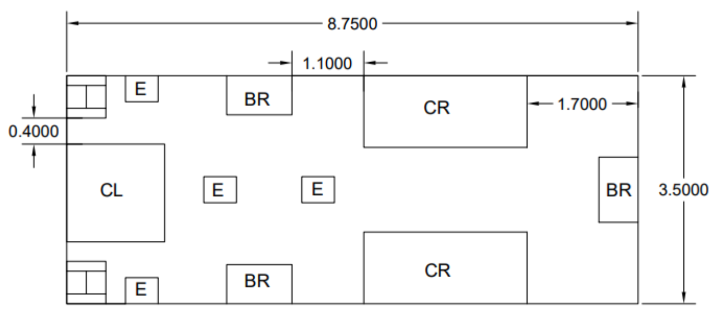
Floor 1 - Basement Level



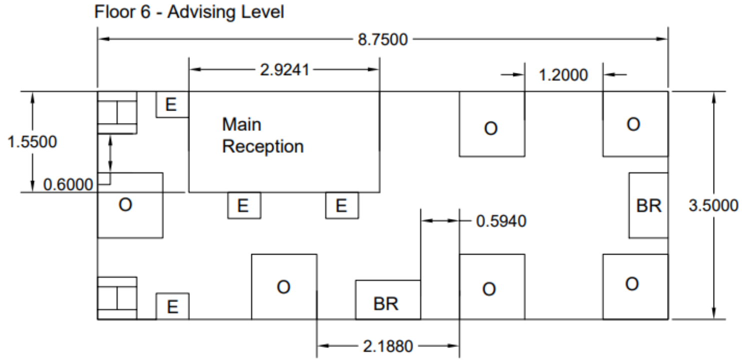
Floor 2 - Ground Level

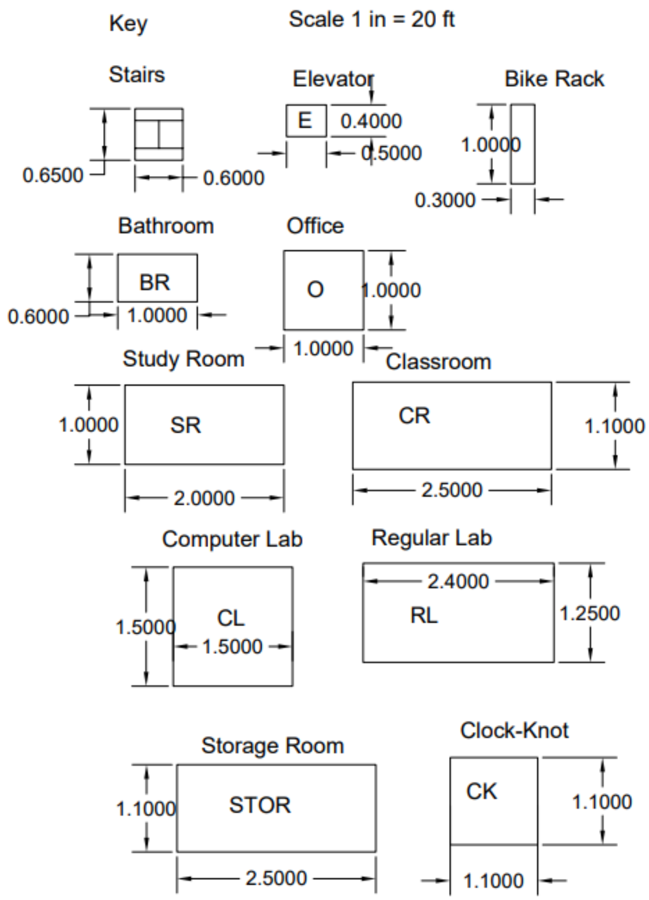


Floors 3-5



Floor 6 - Advising Level




Key
Scale 1 in = 20 ft
Stairs
0.6500
0.6000
Elevator
E
0.4000
0.5000
Bike Rack
1.0000
0.3000
Bathroom
BR
0.6000
1.0000
Office
O
1.0000
1.0000
Study Room
SR
1.0000
2.0000
Classroom
CR
1.1000
2.5000
Computer Lab
CL
1.5000
1.5000
Regular Lab
RL
2.4000
1.2500
Storage Room
STOR
1.1000
2.5000
Clock-Knot
CK
1.1000
1.1000

Appendix B: Transportation Calculations

	G	X	Ci	Di
DEAN KEA	60	0.243539	4295	17.21471
	58	0.251937	4151.833	18.38342
	56	0.260935	4008.667	19.59153
	54	0.270599	3865.5	20.83929
	52	0.281007	3722.333	22.12702
	50	0.292247	3579.167	23.45513

22.70938 60s DK 11 sec Speedway

Must keep DK at 60s due to its volume and weight impacting the avg delay more therefore removing all 4 seconds from speedway.

Speedway	G	X	Ci	Di
	15	0.367867	451.25	50.46829
	13	0.424462	391.0833	53.38689
	11	0.501637	330.9167	57.33241
	9	0.613112	270.75	64.19279
	7	0.788287	210.5833	85.30542
	5	1.103601	150.4167	331.1834
	3	1.839335	90.25	1613.101

Appendix C: Calculations and variables used for Column Design

Dead Load (lbs)		Live Load (lbs)	
Exterior Walls	2,572,500	People & Furniture	4,372,762
Interior Walls	1,893,360	Wind	728,608
Floors	6,431,880		
Doors (12 doors/floor)	7,200		
Windows (36 windows/floor)	4,500		
Pipes	117,740		
Electric	35,802.30		
Total Dead Load (lbs):	**11,062,982**	**Total Live Load (lbs):**	**5,101,370**
Total Dead Load (tons):	**5,531.49**	**Total Live Load (tons):**	**2550.68512**
			Safety Factor of 2:
TOTAL LOAD (Live + Dead) lbs:		**16164352.54**	**32328705.08**
Load Placed on Each Column (lbs/ft^2):		**296890.66**	**593781.33**
Load Placed on Each Column (tons):		**148.45**	**296.89**

Live loads for floors as per building usage	Uniformly distributed load kPa or kN/m2	Uniformly distributed load lb/ft^2
Houses	1.5	31.328
Flats, apartments, motel bedrooms	2	41.771
Offices	3	62.656
Workshops	5	104.427
Parking, vehicle > 2.5 t	5	104.427
Hospitals, school assembly areas with fixed seatin	3	62.656
Dance halls, bars, lounges	5	104.427
Wind load: Main Wind-Force Resisting System: The wind load to be used in the design of the MWFRS for an enclosed or partially enclosed building or other structure shall not be less than 0.5 kN/m2 multiplied by the area of the building or structure projected onto a vertical plane normal to the assumed wind direction. (10.44 lbs/ft^2)		

Assumptions:
Door weight: 100 lbs/door
Window weight: 25 lbs/window
1 ft of wiring for every square foot of area
Aluminum armored cable wiring (typical for commercial buildings)
Aluminum armored cable weight: 0.513 lbs/ft

- **Tributary area** = 15ft x 15ft = 225 ft^2
- **Ratio used to calculate the total load placed on each column:**
  - **Ratio** = $(Tributary\ area \div Total\ load\ of\ one\ floor) \times Total\ load\ of\ building$
    - Tributary area = 225 ft^2

- Total area of one floor = 12,250 ft^2
- Total Load = 32,328,705.08 lbs

- **Compressive Strength:**
    - *Compressive Strength = P (Load placed on one column)÷ A (Base area of a column)*
    - Compressive Strength = 2500 psi
    - P (Load placed on one column) = 593,781.33 lbs
    - Maximum Load Before Buckling:
    - $Max\ Load\ =\ (\pi^2 EI)\ \div\ (KL)^2$
    - E (modulus of elasticity) = 2,000,000 psi
    - I (moment of inertia) = 0.238 lbs·ft^2
    - K (constant for fix-fix support) = 0.5
    - L (length of column) = 10 ft

Appendix D: Python Code

```
1  unitcost = 100
2  mincost = 1e10
3  qmax = 10000000
4
5  for Df in range(2,21):
6      for B in range(2,13):
7          qult = 61680*B**2 + 12336*Df*B
8          print("qult, qmax", qult, qmax)
9          if qult >= qmax:
10             cost= 1500 + 20*Df*(B+1)**2 + 1000*B**2
11             print(Df, B, cost)
12             if cost< mincost:
13                 mincost = cost
14                 mincostDf = Df
15                 mincostB = B
16
17 print("mincostDf, mincostB, mincost", mincostDf, mincostB, mincost)
```

Lines 1 and 2 assign values for the Python program to start with before it narrows into specific values according to our equations, and line 3 creates a variable for our maximum load which incorporates a safety factor of 2. Starting from line 5, we establish a variable (D_f) from a minimum value of 2 ft to a maximum value of 20 ft (21 in script to account for Python range) and did the same for a variable (B) from a minimum value of 2 ft to a maximum value of 12 ft (13 to account for Python range) in line 6. We establish a new variable in line 7 (Q_{ult}) which is equivalent to the load equation we derived earlier. For those ranges, a Q_{ult} and Q_{max} is printed (line 8). Line 9 gives an if statement relating our inequality from before, line 10 represents our cost function, line 12 gives an if statement for testing variables, and lines 13-15 are there to replace variables with every new iteration of the programmed sequence. The final line prints the values of D_f and B that gives us an acceptable load but also the cheapest cost. In plain terms, the program repeats a sequence for D_f & B and keeps testing new combinations all the way through and outputs a final value that abides by both equations. Our final values are: D_f = 8 ft and B = 12 ft with a final cost of $172,540.

References

"Campus Master Plan." Welcome to Planning, Design and Construction, construction.utexas.edu/about-us/campus-master-plan. Accessed 28 Apr. 2024.

EPA, Environmental Protection Agency, www.epa.gov/arc-x/climate-adaptation-and-stormwater-runoff#:~:text=When%20stormwater%20is%20absorbed%20into,events%2C%20can%20increase%20stormwater%20runoff. Accessed 28 Apr. 2024.

"What Is a 100-Year Storm and When Was the Last Time Austin Had One?" What Is a 100-Year Storm and When Was the Last Time Austin Had One? | AustinTexas.Gov, www.austintexas.gov/faq/what-100-year-storm-and-when-was-last-time-austin-had-one. Accessed 28 Apr. 2024.